

**Appendix 2**  
**New Pages 1, 4, 7, 8, 14, 17, & 22**  
**of the specification:**

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FUEL DELIVERY SYSTEM FOR AN INTERNAL COMBUSTION ENGINE  
CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a 35 USC 371 application of PCT/DE 00/04256 filed on November 30, 2000.

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to a fuel delivery system for an internal combustion engine for delivering fuel at high pressure to the injector valves of the engine.

Brief Description of the Prior Art

From German Patent Disclosure DE 195 39 885 A1, a fuel delivery system for an internal combustion engine is already known which has a fuel feed pump and connected in series with it a high-pressure fuel pump, so that fuel at high pressure can be furnished from the high-pressure side of the high-pressure fuel pump, via a pressure line, a reservoir and valve lines, to injection valves, each of which injects fuel directly into one of the combustion chambers of the engine. The fuel feed pump, whose outlet side communicates with the low-pressure side of the high-pressure fuel pump via a pressure line, furnishes fuel that is at pilot pressure to the high-pressure fuel pump.

To keep the pilot pressure in the pressure line at a desired value, a pressure limiting valve is connected to the pressure line via a 2/2-way valve, which either blocks or opens the communication between the pressure line and the pressure limiting valve.

To compensate for the low pumping capacity of the high-pressure fuel pump during the engine starting phase and optionally to scavenge the pressure line on the

From German Patent Disclosure DE 38 36 507 A1, for cooling a control motor of a throttle valve adjusting unit it is known for a flow of coolant water for the control motor to be diverted from the engine coolant system.

## SUMMARY OF THE INVENTION

The fuel delivery system according to this invention has the advantage over the prior art that with the aid of the coolant medium flow, the high-pressure fuel pump can be kept at a temperature level which is below a critical operating temperature of the high-pressure fuel pump. To that end, one or more suitable coolant conduits should be provided, which furnish an appropriate coolant medium flow, which assures adequate heat dissipation, to the high-pressure fuel pump.

Preferably air serves as the coolant medium. If the fuel delivery system of the invention is used in a vehicle engine, then it is possible to dispose the coolant conduits in the engine compartment in such a way that the ambient air, which during vehicle operation is carried from the vehicle surroundings to the high-pressure fuel pump, will suffice for cooling.

However, it is especially expedient if a fan is associated with the at least one coolant conduit, for generating the cooling air flow through the coolant conduit; preferably, the fan is controllable as a function of the temperature of the high-pressure fuel pump and the critical operating temperature. In this way, the cooling

pump on the low-pressure side, that is, the pilot pressure, as a function of the operating conditions of the high-pressure fuel pump.

Expediently, the pressure regulator device is controllable such that the pressure delivered to the low- pressure side of the high-pressure fuel pump can be regulated to a first or a second value. However, it can also be provided that the regulated pressure delivered to the low- pressure side of the high-pressure fuel pump is variable.

To assure safe operation of the high-pressure fuel pump even in extreme cases, expediently at least two coolant conduits are provided, of which one delivers air and the other water as coolant medium to the high-pressure fuel pump.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the invention will become apparent from the detailed description contained below, taken in conjunction with the drawings, in which:

Fig. 1, a schematic, simplified block diagram of a fuel delivery system of the invention, with an air-cooled high- pressure fuel pump;

Fig. 2, a schematic, simplified block diagram of a fuel delivery system of the invention, with a high-pressure fuel pump cooled with a liquid coolant medium, such as water; and

Fig. 3, a flow chart for the operation of a fuel delivery system of the invention, in which the pilot pressure can be regulated and the high-pressure fuel pump can be cooled with a controllable coolant medium flow.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the various drawing figures, components corresponding to one another are identified by the same reference numerals.

As Fig. 1 shows, a fuel delivery system of the invention has a fuel feed pump 10 and a high-pressure fuel pump 11, in order to furnish fuel from a fuel tank 12 via a pressure line system 13 to one or more injection valves 14 of an internal combustion engine. In the exemplary embodiment shown, the assumption is a four-cylinder internal combustion engine, in which each combustion chamber is assigned one injection valve, which injects fuel either directly into the combustion chamber or into its intake region.

The fuel feed pump 10, which is driven in a manner not shown in detail by an electric motor, has its compression side in communication, via a pressure line 15, with a low-pressure side of the high-pressure pump 11. The output or high-pressure side of the high-pressure pump 11 is connected via a further pressure line 16 to the pressure line system 13, to which a pressure sensor 17 is assigned, whose output signal, corresponding to the fuel pressure in the pressure line system 13, is delivered to a control circuit 18, which in a manner not shown monitors the operating

The mode of operation of the fuel delivery system shown in Fig. 2 during normal operation of an internal combustion engine will now be described in conjunction with Fig. 3.

As soon as the engine is started, that is, as soon as the starting phase has ended and the high-pressure pump 11 supplies the injection valves 14, via the pressure line system 13, with fuel at high pressure, the cooling of the high-pressure pump 11 is actuated as well. After the cooling control has started, first in step S11 the temperature  $T_{KS}$  of the flow of coolant water is ascertained with the aid of the temperature sensor 34, and the temperature  $T_{HDP}$  is ascertained with the aid of the temperature sensor 24. In step S12, it is ascertained whether the temperature  $T_{KS}$  of the coolant water is higher than the temperature  $T_{HDP}$  of the high-pressure pump 11. Since normally this is not the case, the control proceeds to step S13, in which it is asked whether the coolant flow is opened, i.e., whether the blocking valve 32 in the coolant conduit 31 is opened. If not, then the blocking valve 32 is opened. After that, in step S14, it is ascertained whether the temperature  $T_{HDP}$  of the high-pressure pump 11 is higher than a first critical operating temperature  $T_{k1}$ . If not, then in step S15 the question is asked whether the low pilot pressure in the pressure line 15 is set, and if not, it is so set. In step S16, normal operation is thus detected, and the control returns to step S11, in order to detect the temperature  $T_{KS}$  of the coolant water and the temperature  $T_{HDP}$  of the high-pressure pump again.

If in step S14 it is ascertained that the temperature  $T_{HDP}$  of the high-pressure pump 11 is higher than the critical operating temperature  $T_{k1}$ , then the control

evaporate could be detected and taken into account, for instance via a fuel warning indicator, for which a fuel gauge is for instance evaluated. If the fuel vapor pressure is known either from a model or by measurement, then more-precise adaptation of the critical operating temperatures to the boiling point of the particular fuel used is possible.

Instead of the direct measurement of the temperatures  $T_{KS}$  and  $T_{HDP}$  of the coolant flow and of the high-pressure pump 11, as shown, these temperatures can also be estimated, using suitable models, from known variables such as the engine temperature, aspirated air temperature, vehicle speed, triggering of the engine fan, and so forth.

By means of the cooling of the high-pressure pump 11 as provided for according to the invention, its temperature  $T_{HDP}$  is kept below the first critical operating temperature  $T_{k1}$  for the great majority of the engine operating time. Thus for the great majority of the engine operating time, a low pilot pressure is sufficient. Only under extreme operating conditions must a pressure switchover accordingly be done. As a result, in particular the load on the fuel feed pump 10, which functions with an electric motor, is reduced considerably, thus increasing its service life. Furthermore, the average power consumption of the fuel feed pump 10, i.e. of the electric motor driving the fuel feed pump 10, is reduced markedly, thus lessening the burden on the on-board electrical system and reducing fuel consumption and tank heating as well.

The foregoing relates to preferred exemplary embodiment of the invention, it being understood that other variants and embodiments thereof are possible within the spirit and scope of the invention, the latter being defined by the appended claims.